Preliminary analyses of prey consumption of three baleen whales and their interaction with fisheries in the western North Pacific

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ABSTRACT

The stomach contents of common minke whale *Balaenoptera acutorostrata*, Bryde's whale *B. edeni*, sei whale *B. borealis* sampled off Pacific region from May to September as part of the 1996-2003 JARPN II, were analyzed. The main prey species of common minke whale consisted of one krill (*Euphausia pacifica*) and two fish (Japanese anchovy *Engraulis japonicus* and Pacific saury *Cololabis saira*). The main prey species of Bryde's whale consisted of one krill (*Euphausia pacifica*) and one fish (Japanese anchovy). There were seasonal, geographical and yearly changes of prey species in western North Pacific. The main prey species of sei whale consisted of two copepods (*Neocalanus cristatus*, *N. plumchrus*), one krill (*Euphausia pacifica*) and two fish (Japanese anchovy and Pacific saury). The body length of Japanese anchovy in the stomachs differed among whales. In western North Pacific, the total annual prey consumption of Japanese anchovy and Pacific saury by three baleen whales were estimated as 2,720,000 tons and 230,000tons, respectively. Based on these results, there is a possibility of direct competition between these whale and the fisheries for these resources in western North Pacific. To evaluate this competition, more information of accurate abundance in prey species and these whales, and resident period of them off Pacific region are needed.

KEYWORDS: COMMON MINKE WHALE; BRYDE'S WHALE, SEI WHALE, NORTH PACIFIC; FISHERIES INTERACTION, SCIENTIFIC PERMIT

INTRODUCTION

Sustainable use of marine living resources is only way people have to choice. However, we have responsibility to evaluate and clear interactions between marine life and fisheries, because fishery industry can easily cause the depletion. Baleen whales, which attained an ability to eat small zooplankton to fish, play an important role in the food chain because of their large abundance.

The common minke whale *Balaenoptera acutorostrata* is widely distributed in the world. In the western North Pacific two stocks have been recognized: one in the Sea of Japan - Yellow Sea - East China Sea (J stock) and the another in the Sea of Okhotsk – West Pacific (O stock) (IWC, 1983). The abundance of minke whales was estimated to be 19,209 animals with 95 % confidence interval (10,069 – 36,645) in the Sea of Okhotsk and 5,841 animals with 95 % confidence interval (2,835 – 12,032) in the Northwest Pacific during August and September in 1989 and 1990 (IWC, 1992). In the western North Pacific, common minke whales are opportunistic feeders with a broad diet and with flexible feeding habits. According to previous reports, they consume several prey species such as pelagic schooling fish and zooplankton (Kasamatsu and Hata, 1985; Kasamatsu and Tanaka, 1992).

The Bryde's whale *B. edeni* is distributed in tropical and warm temperate waters throughout the year, in which the surface temperature is above 16.4 ^{o}C (Ohsumi, 1977). The abundance of Bryde's whales in the western North Pacific was estimated to be 25,300 animals with 95 % confidence interval (17,700 – 36,200 (Okamura and Shimada, 1999). Their feeding habits in the Northwest Pacific have been reported several authors. Bryde's whales fed on krill, Japanese anchovy (*Engraulis japonicus*) and Chub mackerel (*Scomber japonicus*) off the Sanriku Coast, krill and lantern fish in the waters around Bonin Islands, and Japanese sardine (*Sardinops melanostictus*), Japanese anchovy and horse mackerel (*Trachurus japonicus*) off the West coast of Kyushu. In Japanese pelagic operations from 1952 to 1971, Bryde's whales fed on euphausiids (89 %) and fishes (11 %), indicating euphausiids and fish are main prey for Bryde's whale (Nemoto, 1959; Nemoto and Kawamura, 1977).

The sei whale *B. borealis* is widely distributed in the world's ocean. In the western North Pacific one stock (west of 180 longitudinal degrees, excluding the Sea of Okhotsk, the Bering Sea and the Sea of Japan) have been recognized. The abundance of sei whales was estimated to be 28,400 animals with 95 % confidence interval (13,100 – 61,600). In sub-areas 7, 8 and 9, the abundance was estimated to be 9,856 animals (Government of Japan, 2002a). The sei whale is

known to feed on a wide spectrum of marine animals such as krill, Japanese anchovy, chub mackerel, Pacific saury and Japanese common squid. According to Nemoto (1962), sei whales feed mainly copepods in the northern part of the North Pacific, but they likely feed on fishes and squids in the Sanriku and Hokkaido coastal waters of Japan. There is also a report, which shows some sei whales ingested Pacific saury in the southern Aleutian waters. Twenty three species of zooplankton, 8 species of fishes and one species of squid were reported from stomachs of sei whales (Nemoto, 1959; Kawamura, 1982).

The overall goal of the JARPN II was to contribute to the conservation and sustainable use of marine living resources including whales in the western North Pacific, especially within Japan's EEZ. In this JARPN II research special attention was paid to the ecosystem surrounding cetaceans, and the data and materials related to cetaceans, prey species and oceanographic conditions were collected. The main objectives of this research are the following:

1. Feeding ecology and ecosystem studies, involving studies of prey consumption by cetaceans, prey preferences of cetaceans and ecosystem modelling.
2. Monitoring environmental pollutants in cetaceans and the marine ecosystem.
3. Stock structures of whales.

The research area includes sub-areas 7, 8 and 9 and the target species and sample sizes were set as follows: 150 common minke whales (100 in the offshore survey and 50 in the coastal survey); 50 Bryde's whales (offshore survey); 50 sei whales (offshore survey) and 10 sperm whales (offshore survey) (Government of Japan, 2002a).

In this document, the abundances of common minke, Bryde's, sei whales were estimated. And the consumption of targeted fisheries species by these whales was calculated. Then, the interaction was evaluated by the comparison between the prey consumption by these whales and fisheries catches.

MATERIALS AND METHODS

The abundance and average body weight of common minke, Bryde's and sei whales in western North Pacific

The following abundance and average body weight of common minke, Bryde's and sei whales in western North Pacific were used (Table 1).

1. Common minke whale: The abundance of common minke whales was estimated to be 19,209 animals with 95 % confidence interval (10,069 – 36,645) in the Sea of Okhotsk and 5,841 animals with 95 % confidence interval (2,835 – 12,032) in the Northwest Pacific during August and September in 1989 and 1990 (IWC, 1992). In sub-areas 7, 8 and 9, the abundance was estimated to be 11,521 animals. The average body weight is 4.3 tons (Average body weight based on 1994 JARPN – 2003 JARPN II results).
2. Bryde's whale: The abundance of Bryde's whales in the western North Pacific, was estimated to be 25,300 animals with 95 % confidence interval (17,700 – 36,200). In sub-areas 7, 8 and 9, the abundance was estimated to be 2,439 animals (Okamura and Shimada, 1999). The average body weight is 13.5 tons (Average body weight based on 2000–2003 JARPN II results).
3. Sei whale: The abundance of sei whales in the western North Pacific, was estimated to be 28,400 animals with 95 % confidence interval (13,100 – 61,600). In sub-areas 7, 8 and 9, the abundance was estimated to be 9,856 animals (Government of Japan, 2002a). The average body weight is 20.8 tons (Average body weight based on 2002 and 2003 JARPN II results).

The daily prey consumption by whales

We calculated daily prey consumption using the rate of prey intake per body weight of each cetacean species per day (feeding rate: % of body weight) and average body weight. This terminology of 'the feeding rate' was proposed by Sergeant (1969). Some researchers have estimated the prey consumption by cetaceans on the basis of energy–requirement (*e.g.* Hinga, 1979, Lockyer, 1981a, Armstrong and Siegfried, 1991; Tamura and Fujise, 2000a, 2002a). In this study, we estimated the daily prey consumption and feeding rate by each cetacean species based on the following three methods (Tamura, 2003).

Method-1 Estimation of daily prey consumption from average body weight

Innes *et al*.(1986) proposed the following method to estimate daily prey consumption of a cetacean from its average body weight:

$$I = 0.42M^{0.67} \qquad (1)$$

where I is daily prey consumption (kg per day) and M is average body weight (kg).

Method-2 Estimation of daily prey consumption from the standard metabolism

Sigurjónsson and Víkingsson (1997) proposed a method for estimation of daily prey consumption from the standard metabolism of each cetacean species. The daily prey consumption is given by:

$$D = 206.25M^{0.783};\ I = D/1{,}300 \quad (2)$$

where D is daily caloric value of prey intake (kcal per day), M is average body weight (kg) and I is daily prey consumption (kg). We assumed that estimated caloric values of prey were 1,300 kcal/kg for baleen whales in Northern Hemisphere in the world (Steimle and Terranova, 1985).

Method-3 Estimation of daily prey consumption from Klumov's formula

Klumov (1963) proposed a method for estimating daily prey consumption from the average body weight of each cetacean species. The daily prey consumption is given in the following formula by him:

$$I = 0.035M \quad (3)$$

where I is daily prey consumption (kg per day), M is average body weight (kg)

The each calculated daily prey consumption by whales is shown in Table 2. We used the average of three values.

Sampling of the stomach contents

Biological research such as measurement of body proportion were conducted for all whales sampled. The stomach contents were all removed. After that the stomach contents were all removed. The contents from each stomach were weighed to the nearest 0.1 kg, and sub-sample were removed from all individuals and frozen for later examination. The contents were first classified to major prey groups, such as euphausiids, copepods, fish and others. The freshness of stomach contents was categorized into four classes (1 = fresh, 2 = lightly digested, 3 = moderately digested, 4 = heavily digested).

The sub-samples were identified to the lowest taxonomic level as much as possible. When undigested fishes were found, standard lengths and weight were measured to the nearest 1 mm and 1 g, respectively. When fishes occurred in the sub-samples, the total number of each prey species was estimated by adding the number of undigested specimens and the number of intact skulls. The total weight of each prey species was estimated by using the average weight of fresh specimens. The total number and weight of each prey species were estimated by using the results from the sub-samples. Then, the relative prey importance by weight of each prey species (RW) was calculated as follows:

$RW = (W_i / W_{all}) \times 100$

W_i = the weight of contents containing prey group i

W_{all} = the total weight of contents analyzed.

The prey species and composition in the stomach of whales from May to October

Based on JARPN and JARPNII results, the prey species of each whale was shown in Table 3. The diet composition (RW) of whales during feeding period in each sub areas showed in Table 4. It was assumed that the baleen whales spend about 180 days in the feeding areas in the western North Pacific (Ohsumi, 1980, 1982). Lockyer (1981b) reported that the daily prey consumption by Antarctic minke whale in winter was equivalent to 10 % of that in the summer. The seasonal prey consumption of whales during feeding period in each sub areas showed in Table 4.

RESULTS

Diversity of prey species

Common minke whale

A total of seventeen prey species, including 1 copepoda, 4 euphausiids, 1 squid and 11 fishes were identified in the stomachs of common minke whales based on JARPN and JARPN II surveys. Major prey species were *Euphausia pacifica*, Japanese anchovy, Pacific saury (*Cololabis saira*), Japanese sand lance (*Ammodytes personatus*), walleye pollock (*Theragra chalcogramma*) and Japanese common squid (*Todarodes pacificus*).

Bryde's whale

A total of nine prey species, including 3 euphausiids and 9 fishes were identified in the stomachs of Bryde's whales based on JARPN II surveys. Major prey species were krill *E. pacifica* and Japanese anchovy.

Sei whale
A total of eight prey species, including 2 copepods, 2 Amphipods, 1 euphausiid, 2 fishes and 1 squid were identified in the stomachs of sei whales based on JARPN II surveys. Major prey species were 2 copepods (*Neocalanus cristatus*, *N. plumchrus*), 1 euphausiid (*E. pacifica*) and Japanese anchovy.

The daily prey consumption by common minke, Bryde's and sei whales
The average of daily prey consumption weight of common minke, Bryde's and sei whales based on three methods were calculated to be 125 kg, 330 kg and 479 kg, respectively. The average of daily prey consumption rates of common minke, Bryde's and sei whales based on three methods were calculated to be 2.9 %, 2.4 % and 2.3 % of body weight, respectively (Table 2).

The geographical and seasonal changes of prey species of common minke, Bryde's and sei whales
Table 4 shows the prey composition of each whale during feeding period in each sub areas based on JARPN and JARPNII.

The most important prey species of common minke whales were Japanese anchovy and Pacific saury in offshore. The most important prey species in May and June was Japanese anchovy, and Pacific saury from July to September. In sub-area 7, walleye pollock was also an important prey species during May and September.

The most important preys of Bryde's whales were krill and Japanese anchovy in offshore. The most important prey species was krill in May and June, and Japanese anchovy from July to September.

The most important preys of sei whales were copepod, krill and Japanese anchovy in offshore. The most important prey species was copepod in July in sub-area 7 and in June and July in sub-area 9, while Japanese anchovy was the most important one in sub area 8 and in August in sub-area 9.

The prey consumption of common minke, Bryde's and sei whales in western North Pacific
Based on the average of three methods, the estimated total prey consumption by common minke, Bryde's and sei whales weights during feeding period in western North Pacific were 1,040,0000 tons, 2,760,000 tons and 4,500,000 tons, respectively. In JARPN II research area (sub-areas 7, 8 and 9), the estimated total prey consumption of common minke, Bryde's and sei whales weights were 480,000 tons, 270,000 tons and 1,560,000 tons, respectively (Table 5).

The following assumptions were made for calculation.

1. The prey composition of common minke whale in the Sea of Okhotsk was assumed that they fed mainly on krill, herring and walleye pollock (33.3% of wet weight) (Kasamatsu and Hata, 1985).
2. The prey composition of sei whales distributing excluding sub-areas 7, 8 and 9 was assumed that they fed mainly on copepods (75%), krill (15%) and other fishes (10% of total wet weight) (Nemoto, 1962; Kawamura, 1982).

In western North Pacific, the prey consumption of economically important Pacific saury, walleye pollock and herring by common minke whales were calculated as 198,000 tons, 201,000 tons and 192,000 tons, respectively. The prey consumption of economically important chub mackerel by Bryde's whales was calculated as 25,000 tons. The prey consumption of economically important Pacific saury by sei whales was calculated as 29,000 tons (Table 6).

The length composition of Japanese anchovy in the stomach of each whale
Even though, three whale species feed on Japanese anchovy, the sizes of the fish differ. The average body length of Japanese anchovy in the stomachs of common minke whale, Bryde's whale, sei whale, were 123 mm, 97and 119 mm, and from 29 to 70 mm, respectively (Fig. 2).

DISCUSSION

Our estimates of the prey consumption using the three methods, was similar to by Nordøy *et al.* (1995), which investigated the eastern North Atlantic minke whales and these obtained by Lockyer (1981a), which investigated the large baleen whales.

The results of JARPN and JARPN II showed that common minke whales have wide range of feeding habits and it varied both geographically and temporally. This euryphagous is similar to that in Northeast Atlantic.

In western North Pacific, the prey consumption of Pacific saury by common minke whales was calculated as 198,000 tons. In 2002, the total catch of Pacific saury by Japanese fisheries was about 200,000 tons. The biomass of Pacific saury was estimated 8,000,000 tons, but the total consumption of Pacific saury by minke whales was equivalent to the fisheries catch. The fisheries season of Pacific saury is from August to September, and common minke whales also feed on Pacific saury in a same season. The catch quota and season of Pacific saury is regulated by the fisheries conference

in order to protect the resources of Pacific saury and price control; however the consumption of Pacific saury by common minke whales is not considered in catch quota calculation. Our results shows, therefore, consumption by common minke whales should be taken into account for fishery management of Pacific saury in the future.

It was occurred to replacement from Japanese sardine to Japanese anchovy from 1980's in Pacific region of Japan. Kasamatsu and Tanaka (1992) examined annual changes of prey species based on the catch records of small type whaling in the seven whaling grounds off Japan from 1948 to 1987. In Pacific coast of Hokkaido (a part of sub-area 7W) from April to October, prey species recorded were krill, squid, Japanese sardine, Japanese anchovy, chub mackerel, walleye pollock, cod, sand lance, Pacific saury and so on. They noted that the change of prey of common minke whales from Chub mackerel to Japanese sardine in 1977 corresponded with a change of the dominant species taken by commercial fisheries in the same area in 1976. They also reported krill was dominant prey species from 1964 to 1987 in the Okhotsk Sea. In addition, the change of prey species of common minke whales from chub mackerel to Japanese sardine in 1977, from Japanese sardine to Pacific saury in 1996 corresponded with a change of the dominant species taken by commercial fisheries in the same area in 1976, 1996, respectively. Since it is reasonable to assume that common minke whales do not have a strong preference for a particular prey species (Kasamatsu and Tanaka, 1992). The estimated total prey consumption of common minke whales weights during feeding period in western North Pacific were 1,040,000 tons, the composition of prey species probably reflect changes in the abundance of available prey species in the area.

Between 2000 and 2003 JARPN II, the prey species of Bryde's whales in the western North Pacific during May and September, were occupied various pelagic prey species of zooplankton and fishes. Prey species of Bryde's whales varied both geographically and temporally. The dominant prey species of Bryde's whales was krill during May and June, Japanese anchovy between July and September.

In western North Pacific, the biomass of Japanese anchovy estimated to 1,300,000 tons, but the total consumption of Japanese anchovy by Bryde's was more than the biomass of Japanese anchovy. The prey consumption of Japanese anchovy by Bryde's whales was calculated as 1,450,000 tons. Therefore, consumption by Bryde's whales should be taken into account for fishery management of Japanese anchovy in the future.

Between 2002 and 2003 JARPN II, the prey species of sei whales in the western North Pacific during May and September, were occupied various pelagic prey species of zooplankton, fishes and squid. Prey species of sei whales varied both geographically and temporally. The most important prey species of sei whales was copepod in July in sub-area 7, in June and July in sub-area 9, while Japanese anchovy was the most important one in sub area 8 and in August in sub-area 9. In western North Pacific, the prey consumption of Japanese anchovy by sei whales was calculated as 1,050,000 tons. Therefore, consumption by Bryde's whales should be taken into account for fishery management of Japanese anchovy in the future.

The body length of Japanese anchovy ingested by each whale was different. The common minke whales fed mainly on matured Japanese anchovy, on the other hand, Bryde's whales fed mainly on pre-matured Japanese anchovy. This different probably reflect the distribution of Japanese anchovy in the area (Murase *et al*, 2002). It seems that there is size selectivity of prey among whales.

In addition, more data are needed on seasonal, geographical and annual variations in the prey of common minke whales, Bryde's whales and sei whales before conclusions can be drawn with regard to their food consumption in western North Pacific from spring to autumn.

To evaluate the competition between each whale and some fisheries, more information of accurate abundance in prey species and each whale, and the accurate resident period of each whale are needed. Furthermore, there is a need to understand the potential for each whale to have an impact on commercial some fisheries, either directly or indirectly using simulation models for specific geographical regions in future.

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REFERENCES

Armstrong, A.J. and Siegfried, W.R. 1991. Consumption of Antarctic krill by minke whales. *Antarctic Science* 3 (1):13-8.

Government of Japan. 2000a. Research plan for cetacean studies in the western North Pacific under special permit (JARPN II) (feasibility study plan for 2000 and 2001). Paper SC/52/O1 presented to the IWC Scientific Committee, June 2000 (unpublished). 68pp.

Government of Japan, 2002. Research Plan for Cetacean Studies in the Western North Pacific under Special Permit (JARPN II). Paper SC/54/O2 presented to the IWC Scientific Committee, May 2002 (unpublished). 115pp.

Hinga, K.H. 1979. The prey requirements of whales in the Southern Hemisphere. *Deep-Sea Research* 26A:569-77.

Ichii, T. and Kato, H. 1991. Food and daily food consumption of southern minke whales in the Antarctic. *Polar Biol*. 11:479-87.

Innes, S., Lavigne, D.M., Eagle, W.M. and Kovacs, K.M. 1986. Estimating feeding rates of marine mammals from heart mass to body mass ratios. *Marine Mammal Science* 2:227-9.

International Whaling Commission. 1983. Report of the Sub-Committee on minke whales. *Rep. int. Whal. Commn.* 33:91-122.

International Whaling Commission. 1992. Report of the Sub-Committee on North Pacific minke whale. *Rep. int. Whal. Commn.* 42:156-77.

Kasamatsu, F and Hata, T. 1985. Notes on minke whales in the Okhotsk Sea -West Pacific area. *Rep. int. Whal. Commn*. 35:299-304.

Kasamatsu, F. and Tanaka, S. 1992. Annual changes in prey species of minke whales taken off Japan 1948-87. *Nippon Suisan Gakkaishi*. 58:637-51.

Kawamura, A. 1982. Food habits and prey distributions of three rorqual species in the North Pacific. *Sci. Rep. Whales Res. Inst.*, 34:59-91.

Klumov, S.K. 1963. *Feeding and halminth fauna of whalebone whales (Mystacoceti).* Trudy. Inst. Okeanol. 71:94-194.

Lockyer, C. 1981a. Growth and energy budgets of large baleen whales from the Southern Hemisphere. *FAO Fish. Ser*. (5) [*Mammals in the Sea*] 3:379-487.

Lockyer, C. 1981b. Estimation of the energy costs of growth, maintenance and reproduction in the female minke whale, (Balaenoptera acutorostrata), from the southern hemisphere. *Rep. int. Whal. Commn* 31:337-43.

Murase, H., Tamura, T., Kiwada, H., Fujise, Y., Watanabe, H., Ohizumi, H. and Kawahara, S. 2002. Preliminary estimation of prey preference of minke whale and Bryde's whales based on JARPN II. Appendux.5. pp 97-117. *In*: Government of Japan (Fujise, Y., Kawahara, S., Pastene, L.A. and Hatanaka, H. eds.), Report of 2000 and 2001 feasibility study of the Japanese Whale Research Program under Special Permit in the western North Pacific-Phase II (JARPN II). Paper SC/54/O17 submitted to the 54th IWC Scientific Committee Meeting.

Nemoto, T. 1959. Food of baleen whales with reference to whale movements. *Sci. Rep. Whales Res. Inst*. 14:149-290.

Nemoto, T., 1962. Food of baleen whales. *Geiken Sosho*, 4: 136pp. (In Japanese)

Nemoto, T. and Kawamura, A. 1977. Characteristics of food habits and distribution of baleen whales with special reference to the abundance of North Pacific sei and Bryde's whales. *Rep. Int. Whal.Commn* Special issue 1:80-7.

Nordøy, E.S., Folkow, L.P., Mårtensson, P.E. and Blix, A.S. 1995. Food requirements of Northeast Atlantic minke whales. pp. 307-17. In: A.S. Blix, L.Walløe and Ø. Ulltang (eds.) *Whales, seals, fish and man.* Elsevier. [*Developments in Marine Biology*] 4:720pp.

Ohsumi, S. 1977. Bryde's whales in the pelagic whaling ground of the North Pacific. *Rep. int. Whal. Commn* (Special Issue 1):140-50.

Ohsumi, S. 1980. Minke whales in the coastal waters of Japan, 1978. *Rep. int. Whal. Commn* 30: 307-11.

Ohsumi, S. 1982. Minke whales in the coastal waters of Japan in 1980 and a population assessment of the Okhotsk Sea - West Pacific stock. *Rep. int. Whal. Commn* 32:283-6.

Okamura, H. and Shimada, H. 1999. Abundance estimation using muti-year sighting data and the application to the western North Pacific Bryde's whale data. SC/51/RMP18 presented to the IWC Scientific Committee, May 1999 (unpublished). 13pp.

Sergeant, D.E. 1969. Feeding rates of cetacea. *Fisk Dir Skr Ser HavUnders* 15:246-58.

Sigurjónsson, J. and Víkingsson, G.A. 1997 Seasonal abundance of and estimated prey consumption by cetaceans in Icelandic and adjacent waters. *J. Northw. Atl. Fish. Sci*. 22:271-87.

Steimle, F.W. and Terranova, R.J. 1985. Energy equivalents of marine organisms from the continental shelf of the temperate Northwest Atlantic. *J. Northw. Atl. Fish. Sci.* 6:117-24.

Tamura, T. 1998. *The study of feeding ecology of minke whales in the Northwest Pacific and the Antarctic*. D. C. Thesis. Hokkaido University. 125pp. [In Japanese].

Tamura, T., Fujise, Y. and Shimazaki, K. 1998. Diet of minke whales *Balaenoptera acutorostrata* in the Northwestern part of the North Pacific in summer, 1994 and 1995. *Fisheries Science* 64(1): 71-6.

Tamura, T. and Fujise, Y. 2000. Daily and seasonal food consumption by the western North Pacific minke whale Paper SC/F2KJ24 presented to the JARPN review meeting, February 2000 (unpublished). 18pp.

Tamura, T and Fujise, Y. 2002a. Daily and seasonal prey consumption by common minke whale and Bryde's whale in the western North Pacific. Appendix 4. pp 85-96. *In*: Government of Japan (Fujise, Y., Kawahara, S., Pastene, L.A. and Hatanaka, H. eds.), Report of 2000 and 2001 feasibility study of the Japanese Whale Research Program under Special Permit in the western North Pacific-Phase II (JARPN II). Paper SC/54/O17 submitted to the 54th IWC Scientific Committee Meeting.

Tamura, T and Fujise, Y.2002b Geographical and seasonal changes of prey species of minke whale in the Northwestern Pacific. *ICES Journal of Marine Science*. 59:516-528.

Tamura, T. 2003. Regional assessments of prey consumption and competition by marine cetaceans in the world. *In Responsible Fisheries in the Marine Ecosystem*. Pp. 143-70. Ed. By Snclair, M. and Valdimarsson, G. 448pp.

Tamura, T., Konishi, K., Hakamada, T., Matsuoka, K., Murase, H., Miyashita, T., Kishiro, T., Ohizumi, H., Kato, H. and Kawahaera, S. 2004. Preliminary analyses of interaction between common minke whales and fisheries off Kushiro region. Paper SC/56/*** submitted to the 56th IWC Scientific Committee Meeting.

Table 1. The abundance and average body weight of common minke, Bryde's and sei whales in western North Pacific

Species	Westen North Pacific		Sub-areas 7, 8, 9	Body weight
	Abundance	(95% confidence level)	Abundance	(tons)
Common minke whale	25,000	(12,900 - 49,000)	11,522	4.3
Bryde's whale	25,300	(17,700 - 36,200)	2,439	13.5
Sei whale	28,400	(13,400 - 61,600)	9,856	20.8

Table 2. The daily prey consumption of common minke, Bryde's and sei whales in western North Pacific

Species	Daily prey consumption (kg)			Average	Feeding
	Method-1	Method-2	Method-3	(kg)	rate (%)
Common minke whale	114	111	151	125	2.9
Bryde's whale	246	272	473	330	2.4
Sei whale	328	381	728	479	2.3

Table 3. The prey species of common minke, Bryde's and sei whales in western North Pacific

A. Common minke whale

	Prey species	
Main prey	Copepods	*Neocalanus cristatus*
	Krill	*Euphausia pacifica*
		Thysanoessa longipes
		T. inermis
	Japanese sand lance	*Ammodytes personatus*
	Japanese anchovy	*Engraulis japonicus*
	Pacific saury	*Cololabis saira*
	Chub mackerel	*Scomber japonicus*
	Japanese pomfret	*Brama japonica*
	Walleye pollock	*Theragra chalcogramma*
	Pink salmon	*Oncorhynchus gorbuscha*
	Japanese common squid	*Todarodes pacificus*
Minor prey	Krill	*T.inspinata*
	Japanese sardine	*Sardinops melanostictus*
	Coho salmon	*O. kisutch*
	Duckbill barracudina	*Paralepis atlantica atlantica*
	Daggertooth	*Anotppterus pharao*

B. Bryde's whale

	Prey species	
Main prey	Krill	*Euphausia pacifica*
	Japanese anchovy	*Engraulis japonicus*
	Chub mackerel	*Scomber japonicus*
Minor prey	Krill	*E. similis*
		Thysanoessa inspinata
		Decapterus tabl
	Lantern fish	*Diaphus theta*
		Tarletonbeania taylori
	Gonostomatid fish	*Vinciguerria nimbaria*
	Starry toado	*Arothron firmamentum*
	Snipe eel	*Nemichthys scolopaceus*
		Lestidiops jayakari

C. Sei whale

	Prey species	
Main prey	Copepods	*Neocalanus cristatus*
		N. plumchrus
	Krill	*Euphausia pacifica*
	Japanese anchovy	*Engraulis japonicus*
	Pacific saury	*Cololabis saira*
	Japanese common squid	*Todarodes pacificus*
Minor prey	Amphipods	*Themisto japonica*
		T. pacifica

Table 4. The prey composition (% of wet weight) of each whale during feeding period in each sub areas in western North Pacific

A. Common minke whale

Sub area	Month	N	Krill	Anchovy	Saury	Pollock	Squid	Other
7	May-June	156	8.3	84.0	0.0	7.1	0.0	0.6
	July-September	106	22.6	28.3	30.2	12.3	6.6	0.0
8	May-June	67	4.5	89.6	6.0	0.0	0.0	0.0
	July-September	67	3.0	7.5	86.6	0.0	1.5	0.0
9	May-June	81	2.5	72.5	22.5	0.0	0.0	2.5
	July-September	188	8.5	12.8	75.0	0.0	0.0	3.7

B. Bryde's whale

Sub area	Month	N	Krill	Anchovy	Mackerel	Other
7	May	5	80.0	20.0		
	June	41	93.2	4.4	2.4	
	July	14	69.6	24.1	6.4	
	August	21	25.3	74.5		0.17
	September	8	14.9	85.1		
8	June	9	60.0	40.0	0.03	
	July	7		99.9	0.07	
	August	26		99.9	0.05	0.03
9	July	14	28.6	71.4	<0.01	<0.01

C. Sei whale

Sub area	Month	N	Copepods	Krill	Anchovy	Saury	Squid	Other
7	July	3	85.4			14.6		
8	May	3			100.0			
	June	9	10.0	38.1	51.9		0.01	
	July	3			73.9	9.2	16.2	0.7
	September	2			100.0			
9	June	10	77.8	11.1	0.4	10.7		
	July	40	46.4	39.3	11.2	2.5	0.5	0.02
	August	3			94.9			5.1

Table 5. The seasonal prey consumption of each whale during feeding period in western North Pacific

Species	Abundance (inds.)		Body	Daily	Seasonal prey consumption (ten thousand tons)	
	Sub-areas 7, 8 and 9	western North Pacific	weight (tons)	consumption (kg)	Sub-areas 7, 8 and 9	western North Pacific
Common minke whale	11,522	25,000	4.3	125	47.7	103.5
Bryde's whale	2,439	25,300	13.5	330	26.6	276.4
Sei whale	9,856	28,400	20.8	479	156.3	450.4

Table 6. The each prey consumption of each whale during feeding period in western North Pacific

A. Common minke whale

Area	Annual consumption (ten thousand tons)						
	Krill	Anchovy	Saury	Pollock	Squid	Herring	Other
7+8+9	3.2	22.4	19.8	0.9	0.5	0.0	1.0
WNP*	22.4	22.4	19.8	20.1	0.5	19.2	1.0

B. Bryde's whale

Area	Annual consumption (ten thousand tons)			
	Krill	Anchovy	Mackerel	Other
7+8+9	12.4	14.0	0.2	0.0004
WNP	128.7	145.2	2.5	0.005

C. Sei whale

Area	Annual consumption (ten thousand tons)				
	Copepoda	Krill	Anchovy	Saury	Other
7+8+9	28.6	18.2	104.5	29.0	0.0
WNP**	220.6	44.1	104.5	2.9	29.4

*: The prey composition of common minke whale in the Sea of Okhotsk was assumed that they fed mainly on krill, herring and walleye pollock (33.3% of wet weight).

**: The prey composition of sei whales distributing excluding sub-areas 7, 8 and 9 was assumed that they fed mainly on copepods (75%), krill (15%) and other fishes (10% of total wet weight).

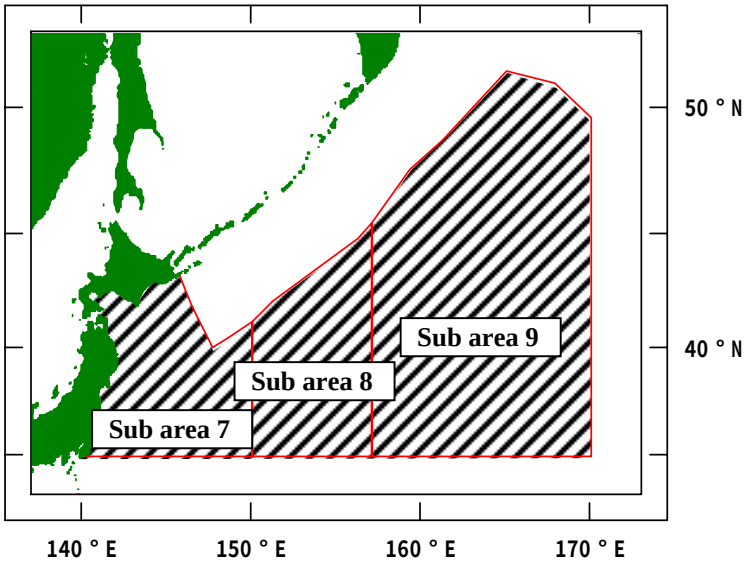
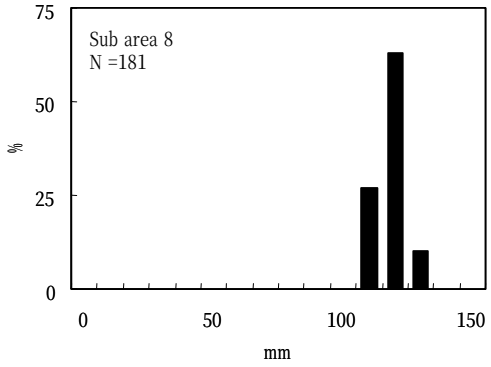
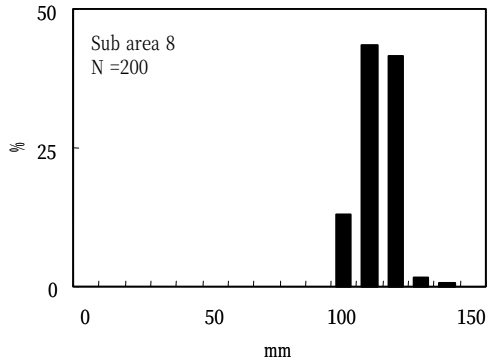


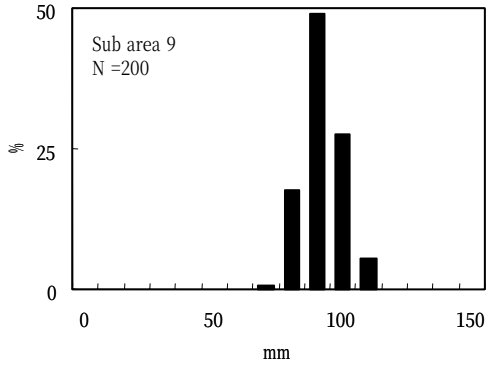
Fig.1. Research area

a. Common minke whale

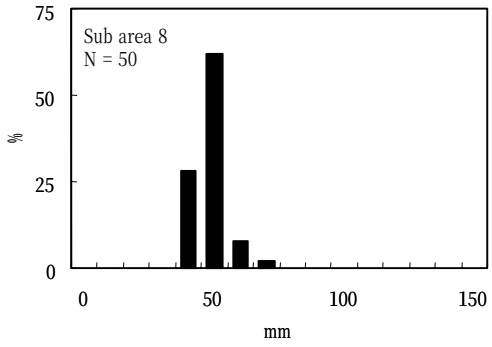


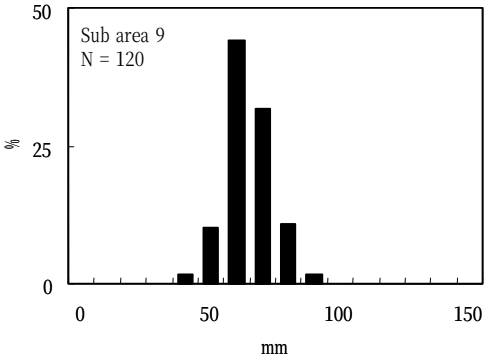
b. Sei whale





c. Bryde's whale





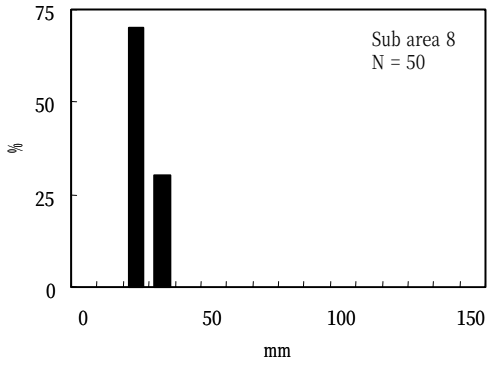


Fig.2. Length composition (*S.L.*) of Japanese anchovy in the stomachs of each whale